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a time-varying heterogeneity approach using survey data

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Abstract. Using Consensus Economics survey data on JPY/USD and GBP/USD exchange rate expectations for the 3- and 12-month horizons over the period November 1989 – December 2012 we first show that expectations fail to unbiasedness tests and do not exhibit a learning process towards rationality. Our approach is consistent with the economically rational expectations theory (Feige and Pearce, 1976), which states that information costs and agents' aversion of misestimating future exchange rates determine the optimal amounts of information on which they base their expectations. The time-variability of the cost/aversion ratios justifies at the aggregate level a representation of expectations as a linear combination of the traditional extrapolative, adaptive and regressive processes augmented by a forward market component, whose parameters are allowed to change over time. This mixed expectation model with unstable heterogeneity is validated by our Kalman Filter estimation results for the two currencies and the two horizons considered. Although the chartist behavior, gathering the extrapolative and adaptive components, appears to dominate the fundamentalist behavior, described by the regressive and forward market components, the relative importance of the fundamentalists (chartists) is found to increase (decrease) with the time-horizon.

Résumé. En exploitant les données d'enquête de Consensus Economics sur les anticipations des taux de change JPY/USD et GBP/USD à 3 et à 12 mois sur la période Novembre 1989 – Décembre 2012, nous montrons que les anticipations ne sont pas rationnelles ni n'exhibent un processus d'apprentissage vers la rationalité. Notre approche est conforme à la théorie des anticipations économiquement rationnelles (Feige and Pearce, 1976) qui stipule que les coûts informationnels et l'aversion des agents à commettre des erreurs de prévision déterminent les quantités optimales d'information sur lesquelles ils fondent leurs anticipations. Du fait de la variabilité temporelle des ratios coût/aversion, nous proposons une représentation au niveau agrégé des anticipations par une combinaison linéaire des processus traditionnels extrapolatif, adaptatif et régressif, augmentée d'une composante de marché à terme, dont les paramètres peuvent changer au cours du temps. Ce modèle mixte d'anticipation avec hétérogénéité variable est validé par nos résultats d'estimation par le filtrage de Kalman pour les deux monnaies et les deux horizons considérés. Bien que le comportement chartiste, fondé sur les composantes extrapolative et adaptative, domine le comportement fondamentaliste, décrit par les composantes régressive et de marché à terme, l'importance relative des fondamentalistes (chartistes) augmente (diminue) avec l'horizon.

1. Introduction

Models of exchange rate determination state that the spot exchange rate is determined as a linear combination of the expected change in exchange rate and of fundamentals.[1] As for the way to measure exchange rate expectations, a usual approach is to assume that expectations are rational.[2] To check for the relevance of this hypothesis, some authors used exchange rate expectations provided by survey data. These authors have found evidence against the unbiasedness of experts' expectations.[3] Since the unbiasedness tests have so far been conducted assuming constant parameters, the REH is rejected only on average over a given period, but not at any time-in-period. To fill this gap, we aim to examine the possible emergence of a group of rational experts during the period of analysis. We then perform a test with stochastic coefficients to check for the presence of a learning process towards rationality. We find that rational learning is strongly rejected, suggesting that no significant group of rational agents appears over time.

On the other hand, the literature using survey data has also shown that none of the three traditional standard expectation processes - these are the extrapolative, adaptive and regressive processes - is sufficient by itself to explain satisfactorily the formation of experts' expectations.[4] These results hold regardless of the source of the survey data, the type of the data used (aggregate or micro data), and the time-horizon of expectations.[5] As pointed out by Prat and Uctum (2007), this failure in modelling how expectations are formed can be the result of two hypotheses most commonly accepted in this literature: (i) one and only one of the three processes prevails *at any time* over the sample period, and (ii) this process is either the extrapolative, or the adaptive, or the regressive one. In fact, a few studies dropped assumption (ii). For example, Frankel and Froot (1986, 1987, 1990) introduce the extrapolative–regressive and the adaptive–extrapolative mixed models. However, the authors do not report any significant results concerning the relevance of these mixed models. By contrast, using Consensus Economics aggregate survey data on various exchange rate expectations, Prat and Uctum (2000) showed evidence of an extrapolative - regressive - adaptive mixed model while Bénassy et al. (2003) confirmed at the disaggregate level this mixing behaviour. Studies aiming at relaxing assumption (i) and thus testing whether the exchange rate expectation process changes over time are very scarce. Although Frankel and Froot (1987) have suggested the idea, they did not model it further. Using survey data for the yen/dollar exchange rate, Ito (1994) has fit a bandwagon model for the one-month-ahead expectations and a mean-reversion model for the 3- to 6-month horizons, and reported that these models were rather stable over time. However, this conclusion is based upon arbitrary sample separation into sub-periods. To avoid this problem, Prat and Uctum (2007) proposed a

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[1] See, among others, Mussa (1976) for the flexible-price monetary model, Calvo and Rodriguez (1977) for the currency substitution model, Krugman (1991) for the target zone model, and Harvey (1999) for the post-Keynesian model.

[2] Note that a growing number of macroeconomic models replace REH by a linear forecasting rule with time-varying parameters (Evans & Honkapohja, 2001; Branch & Evans, 2006).

[3] See Liu and Maddala (1992), Cavaglia et al. (1993), MacDonald (1991, 2000), Prat and Uctum (2013).

[4] Frankel and Froot (1987), Allen and Taylor (1990), MacDonald and Torrance (1990), Cavaglia et al. (1993).

[5] Overviews on these issues are provided by Takagi (1991) and MacDonald (2000).

switching-regime probabilistic model based on a mixture of distributions in which changes in regimes are determined endogenously. According to this model, the state of the nature may be characterized at any time by one of the three standard extrapolative, regressive, and adaptive processes or by any combination of them.[6] Considering six European three-month ahead exchange rate expectations against the US dollar provided by Consensus Economics over the period June 1990 – June 1997, the authors found that both the hypothesis of mixed expectation processes and the one of changes in processes are validated by the data. This approach is based upon the assumption that at any time, the regime – a simple or a mixed process – with the highest conditional probability is the prevailing one. This implies, however, that whenever the highest probability is not largely dominant, ambiguities will arise in identifying the prevailing regime[7].

Rather, this paper aims at analyzing the formation of exchange rate expectations using a mixed model with time-varying coefficients. Our model is consistent with the economically rational expectation theory (ERET) introduced by Feige and Pearce (1976), which states that forecasters accumulate information until the marginal gain equals the unit cost of information. The fact that information is of different types explains why our model is mixed, (ie, combines different expectation components). We further show in the next section that when information costs and agents' aversion to make forecast errors change over time, the coefficients of the model are time-varying. The general model we propose hereafter combines the extrapolative, regressive and adaptive traditional single processes augmented by the forward premium which is supposed to capture some market information. Although a vast empirical literature has shown that the forward premium is not a good predictor of the change in the spot exchange rate[8], for two reasons it makes sense to include this component in our expectation model as an additional component. First, the cost of using this information is *a priori* very small, because it is publicly available. There is therefore no drawback for an agent to employ it even if its contribution to reduce the forecast error is low. Second, the forward premium may prove significant only when it is combined with other components since the exchange market is not efficient. To our knowledge, studies concerned by the estimation of such an augmented mixed expectation process with time varying parameters are very scarce. Perhaps the closest contribution is Ellen et al (2013), who propose a combined expectation model with a momentum rule, a PPP rule and an interest parity rule. These rules are similar to three of our four components, which are the extrapolative, the regressive and the forward

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[6] Note that some other studies have estimated switching-regime models of exchange rate determination, where each regime defines an expectation process. As such, these studies have also implicitly examined the time-varying pattern of expectation process. Among them, Vigfusson (1997) estimates a Markov-switching regime model and finds that chartists' activities explain the exchange rate dynamics in periods of low volatility, whereas fundamentalists' activities represent it in periods of high volatility. Bessec and Robineau (2003) expand the previous model by showing that there exists some coexistence of the two groups in each regime. Nevertheless, these two last studies do not deal explicitly with the question of how expectations are formed. Furthermore, they have only been concerned by the chartist–fundamentalist framework and have never included other expectation behavior.

[7] However, Prat and Uctum's (2007) results do not suffer from this issue since the authors report evidence of dominant probabilities close to one almost at any time.

[8] See in particular Hansen and Hodrick (1980), Fama (1984), MacDonald and Taylor (1989), Cavaglia et al. (1994), Chakraborty and Haynes (2008).

market components, respectively. The authors account for the dynamics of the heterogeneity by assigning to each forecasting rule a weight that captures agents' switching between the rules. Based on Brock and Hommes (1997, 1998), this weight depends on the size of the last forecast error due to this rule. Using weekly survey data on 1-, 3- and 12-month ahead expectations for four exchange rates provided by FX Week over the period 2003-2007, the authors validate the three rules and find evidence of switching behavior of agents over time only at the 12 month horizon. However, variations in the weights are not equally convincing for all the exchange rates as no confidence intervals are provided and, as reported by the authors, a counterintuitive switching mechanism is found in the case of one exchange rate. These questionable findings are possibly due to the fact that the switching criterion described by the weighting functions is too restrictive, albeit insightful, to explain by itself the dynamics of the heterogeneity. However the fact that the switching criterion is lagged precludes any switching decision that may be driven by a change in the state of the nature between the last and the actual periods. As we will show below, the ERET framework allows to avoid this drawback as the decision criterion is dated at time t, which means that all information can be taken into account instantly. In this setting, the aforementioned reference to the past forecast error can be viewed as a consequence of the aversion to making forecast errors. Thus the dynamic cost-advantage framework to which we refer is more general although it does not allow to estimating an explicit switching rule as in Ellen et al (2013). To estimate the time-varying weights associated with the four components of our exchange rate expectations model, we implement the Kalman filter methodology (Harvey (1992) and Hamilton (1994). The Kalman filter method is suitable for representing at the aggregate level the continuous revision of information process suggested by the ERET. We estimate our mixed expectation model with time-varying parameters for two major currencies, the Japanese Yen and the British Pound, both against the US dollar (JPY/USD and GBP/USD). For each currency our model simultaneously describes the 3-month and the 12-month ahead expectation formation. We measure expectations using monthly surveys provided by Consensus Economics.

The paper is organized as follows. In Section 2 we show that the ERET provides an appropriate theoretical framework to explaining expectation formation on the basis of a cost and advantage analysis. According to this framework, rational expectations appear to be contingent to very restrictive conditions while time-varying information costs of different types lead forecasters to rely on a combination of limited-information expectation processes whose weights evolve over time. In Section 3 we discuss the specification of our mixed expectation model with time-varying weights. In Section 4 we present the data and test whether the 3- and 12-month expectations provided by survey data are rational and whether there is a learning effect over time towards rationality. The empirical results of our model are then presented. Section 5 provides concluding remarks.

2 - Theoretical issues

2.1. The economically rational expectations at the individual level

According to the ERET proposed by Feige and Pearce (1976), the expectation process is derived from a cost-and-advantage analysis of information. Let I_{it}^j be the amount of information of type i (i=1,2,…,n) available to forecaster j at time t and c_{it}^j the price of collecting and processing a unit of this information supported by this agent. Types of information are actual and past values of the exchange rate, macroeconomic variables and observable stochastic shocks; in a broader sense, the notion of type includes the form in which information is used. Assuming constant returns to scale, c_{it}^j is a marginal cost. Let f be a twice continuously differentiable function linking the information inputs I_{it}^j to the agent's expected quadratic forecast error. We assume[9]:

$$E_t(E_t^j s_{t+\tau} - s_{t+\tau})^2 = f(I_{1t}^j,...,I_{it}^j,...I_{nt}^j) \qquad f_i^{'} < 0, \quad f_i^{''} > 0 \quad i = 1,...n \qquad (1)$$

where s_t is the logarithm of the spot exchange rate and $E_t^j s_{t+\tau}$ is the logarithm of the expected exchange rate by agent j at time t for the horizon τ.

The signs of the first and second derivatives of f mean that the more an agent collects information the more they expect to reduce the squared forecast error, the marginal efficiency of information decreasing as the amount of information increases. To determine the optimal amount of each type of information, the forecaster minimizes at any time their total cost

$$C_t^j = \pi_t^j f(I_{1t}^j, I_{2t}^j,...I_{nt}^j) + \sum_{i=1}^{n} c_{it}^j I_{it}^j, \qquad (2)$$

where $\pi_t^j > 0$ is the agent's aversion of misestimating future exchange rates so that $\pi_t^j f(.)$ represents their loss function. This loss function is therefore perceived as being all the more large than aversion is high. At the equilibrium, equation (2) implies:

$$c_{it}^j = -\pi_t^j df / dI_{it}^{j*}, \qquad i = 1, 2,…, \text{n} \qquad (3)$$

According to (3), the optimal amount of information I_{it}^{j*} used by agent j is such that the marginal gain (i.e. the marginal decrease in the loss function) equals the unit cost. When at time t the cost/aversion ratio c_{it}^j / π_t^j tends to zero for each type of information i ($c_{it}^j \to 0$ or $\pi_t^j \to \infty$), the forecaster uses all available information such that the forecast error variance is minimal; this means that information is used until the marginal gain is vanished, this case

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[9] Our theoretical approach is in line with Feige and Pearce (1976) but departs from it on two main aspects: (i) we relate information used to the expected quadratic error and not to the ex-post quadratic error, so that f is clearly a behavioural function in (1); (ii) we relax the assumption that informational costs and preferences of agents are constant over time and allow these magnitudes to be time-varying.

corresponding to the muthian rationality.[10] At the opposite, if the value of the cost/aversion ratio is prohibitively high (typically when information is too costly or agents are not averse to forecast errors), the forecaster ignores all information and thus behaves as a noise-trader by forming naive expectations. More generally, the forecaster accumulates information until $-df/dI_{it}^{j}$ equals c_{it}^{j}/π_{t}^{j} even though the additional information collected allows for a weak decrease in the forecast error, which is the case when the cost/aversion ratio is low. Overall, the existence of information costs suggests that it may be rational for agents not to anticipate rationally, because purchasing all available information whatever its price may prove more costly than the forecast error resulting from the unused but relevant information. Most likely, the optimal situation for most forecasters lies between the two extreme cases that are the ones of rational expectations and naïve expectations. In this context, the question is to identify what is the set of information on which agents base effectively their actual forecasts.

However, the cost/aversion ratio is not an observable magnitude and therefore its implication in terms of information included in the forecasting process is not directly measurable. For any type of information i, the cost/aversion ratio c_{it}^{j}/π_{t}^{j} in equation (3) is made of individual characteristics of agent j, which can themselves change over time according to the state of the nature[11]. For example, an increasing instability of the economy may require more complex statistical tools to make forecasts, and thus push up the cost of processing information during the turmoil period. Simultaneously, the instability may also lead to a progressive rise in the agent's aversion to make forecast errors, such that the overall effect on the cost/aversion ratio can be an increase for some forecasters and a decrease for some others. These cost/aversion ratio discrepancies across agents imply that the amount of information used of a given type differs from one agent to the other. In addition, each agent can combine in their own way different types of information according to the vector of costs they face, basing their forecast upon one or several type(s) of information. This leads, at the aggregate level, heterogeneous expectations that are given by a weighted average of expectations emanating from the various groups of forecasters, where the magnitudes of the weights reflect the proportions of forecasters inherent to the groups. Because condition (3) is time-dependent, so is the structure of heterogeneity. This implies that the weights associated with the groups are continuously time-varying.

2.2. From the perceived law of motion to the expectation process at the aggregate level

In this section we show that the heterogeneous expectations produced by costly information at are also biased. Let X_{it}^{j} be the vector of observable variables corresponding to I_{it}^{j*}. Suppose that the actual law of motion of exchange rate is given by a linear combination of n variables,

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[10] Muth (1961).

[11] Note that π_{t}^{j} is similar to the risk aversion coefficient, which is sometimes supposed to be time-varying. For example, Barberis et al. (2001) explain the equity premium puzzle by the fact that the risk aversion coefficient depends on the state of the nature.

all of them being one period lagged, that is $s_t = \sum_{i=1}^{n} a_i X_{i,t-1} + \varepsilon_t$ where s_t is the logarithm of

the spot exchange rate, ε_t a white noise and X_{it}'s different types of variables, such as

stochastic shocks, autoregressive or mean-reversion components, lagged forward rate… If

agents perceive the actual law of motion with no perception bias and no cost, then the one-

period ahead expected exchange rate is $E_t^j s_{t+1} = \sum_{i=1}^{n} a_i X_{it} \;\; \forall j$ and the forecast error is

$s_{t+1} - E_t^j s_{t+1} = \varepsilon_{t+1}$, i.e. a white noise, meaning that expectations are rational for all agents.[12]

Suppose now that at some period t the value of the cost/aversion ratio for an agent j exceeds

the marginal gain allowed by the use of, say, the predictor X_{nt} and that there is no parameter

perception bias for the *n-1* remaining variables. Agent j will then exclude X_{nt} from the set of

their predictors and form the forecast $E_t^j s_{t+1} = \sum_{i=1}^{n-1} a_i X_{it}$. Obviously, this expectation is biased

since the forecast error $s_{t+1} - E_t^j s_{t+1} = a_n X_{nt} + \varepsilon_{t+1}$ now includes the omitted variable.[13]

Generally speaking, at the individual level, the decision process in using or not a given

variable according to its cost introduces a discontinuity in the selection of predictors at any

time. However, this discontinuity does not hold for aggregate expectations, since the expected

exchange rate will depend on the variable in question at any time there exists a significant

proportion of forecasters employing this variable, jointly or not with other variables. Hence,

the coexistence of different groups of forecasters makes the aggregate expectations both

heterogeneous and biased, although these expectations are economically optimal in the sense

of the ERET. These two properties of expectations are evidenced by studies using survey

data.[14]

Some studies are based on questionnaire surveys where traders in the foreign exchange

market are asked directly what forecasting method they use (Allen and Taylor, 1990; Taylor

and Allen, 1992; Oberlechner, 2001). These studies provide a good illustration of how a

perceived law of motion yields to the selection of an expectation process. From these surveys

it turns out that "short-term" expectations (generally up to one month) appear to be rather

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[12] If the change in the exchange rate is perceived as a sequence of stochastic observed shocks, it can be shown that the adaptive model is the expectation process used (Muth, 1960). If, alternatively, change in the exchange rate is perceived as having an autoregressive representation, the expectation model used is of the extrapolative form (Baillie and MacMahon, 1992). If exchange rate exhibits a mean-reversion feature, a regressive expectation model is employed by the forecaster (Holden et al., 1985). Of course, the forecaster can perceive a complex law of motion defined by a combination of the preceding type of dynamics, and it can be shown that the expectation model s(he) employs is a general model mixing the extrapolative, regressive, adaptive components.

[13] Another source of discrepancy between the perceived and actual laws of motion may arise from the case where X_{nt} is included in the perceived law of motion but with a wrong value of its coefficient. According to the ERET framework, this would mean that *processing* information is too costly to achieve the actual law of motion.

[14] See, among others, Ito (1990), MacDonald and Marsh (1996), Bénassy-Quéré et al. (2003), and also MacDonald (2000) for a survey. Note that the forecast bias could be interpreted as a "peso effect" (Kraster (1980), Kaminsky (1993)). However, this would imply that expectations are homogeneous, which is rejected by survey data.

dominated by technical analysis (chartist forecasters), whereas "long term" expectations - generally exceeding a 12-month horizon - are rather based on fundamentals (fundamentalist forecasters).[15] While the chartists refer to past values of exchange rate, fundamentalists believe that some macroeconomic variables drive the exchange rate towards a "normal" value.[16] The coexistence of these two groups of forecasters among the experts surveyed motivates us to account for these two types of behaviour in modelling our aggregate 3-month and 12-month ahead expectations. This can be achieved by appropriately mixing the traditional expectation processes, even though the literature has evidenced the inadequacy of each of these processes to explain expectations by itself (see introduction). In fact, such a mixture of processes at the aggregate level can stem from two kinds of situations: (i) the market comprises different groups of agents, each of them using a simple process (group-heterogeneity effect); (ii) all forecasters use a mixed process defined as a combination of simple processes (individual weighting effect). Because groups in case (i) may also be made of forecasters using mixed processes, the two effects may operate simultaneously. Interestingly, from a survey of the methods used to forecast four European foreign exchange rates, Oberlechner (2001) report that most traders adopt both fundamental and chartist approaches while distinct groups of traders use one or the other of the two forecasting methods, depending on the horizon considered. These findings clearly support the effects (i) and (ii) and confirm the relevance of a mixed model.

3. The expectation model

As explained in section 2.2, we suppose that at any point in time, the aggregate expected change in exchange rate $E_t s_{t+\tau} - s_t$ is represented by a combination of four basic expectation components. These are the extrapolative, the regressive, the adaptive and the forward-market components, denoted $EXT_{t,\tau}, REG_{t,\tau} ADA_{t,\tau}$ and $FOR_{t,\tau}$, respectively. Consistently with our ERET framework, we allow the structural parameters of these components to change over time. We moreover argue that the parameters of the first two components may take any sign.

The *extrapolative component* is defined as a linear function of the past variations of the exchange rate. Preliminary results led us to select three lags whose parameters were found to be non-significantly different one from the other, so that our extrapolative component is the rate of change observed during the three last months:

$$EXT_{t,\tau} = a_{t,\tau} \ (s_t - s_{t-3}) \tag{4}$$

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[15] For the US forex, see Frankel (1987), Frankel and Froot (1990), Taylor and Allen (1992), Ito (1994), Lui and Mole (1998), and Cheung and Chinn (2001). For European foreign exchange markets, see and Menkhoff (1997), Oberlechner (2001), and Cheung et al. (2004).
[16] Mark (1995) finds evidence of a relation between multiple-period long term changes in exchange rate and the deviations of the exchange rate from its fundamental value represented by a monetary model. This allows the author to state that "long-horizon changes in log nominal exchange rates contain an economically significant predictable component".

Although the theoretical sign of the parameter a_τ is more likely to be positive, a negative value is conceivable in the extent that it can reflect a naive regressive process, describing a systematic turning tendency. The *adaptive component* is proportional to the last observable forecast error, that is the difference between the exchange rate forecast generated τ months before and the observed spot rate. But it is possible, indeed very likely, that experts will not wait until the three month horizon is completed to revise their expectations. When, during the survey procedure, the spot rate at the beginning of the month is known, the individuals will probably compare this rate to the exchange rate which they had expected during the last survey, i.e., a month before, and not three months before as the standard adaptive model assumes.[17] Our adaptive component based on an "early revision" mechanism of forecast errors is therefore written as:

$$ADA_{t,\tau} = b_{t,\tau}(E_{t-1}s_{t+\tau-1} - s_t) \tag{5}$$

where $0 < b_\tau < 1$, $\forall \tau$. The *regressive component* states that the expected change in exchange rate depends on the deviation between the long-run equilibrium value of the exchange rate $\bar{s}_t$ and the actual spot rate, such that

$$REG_{t,\tau} = c_{t,\tau}(\bar{s}_t - s_t) \tag{6}$$

In the standard form of the regressive component, we have $0 < c_\tau < 1$. When the currency is undervalued (overvalued) with respect to its equilibrium level, forecasters who believe in a temporary misalignment expect that the currency will follow a mean–reverting path and therefore will appreciate (depreciate). We nevertheless allow the case $c_\tau < 0$, which says that a majority of forecasters expect a deviation from the reference value to be amplified in the same direction. This characterizes an explosive process in expectation formation, at least over the horizon τ, after which beliefs can be reversed. We assume that the equilibrium value $\bar{s}_t$ is given by the purchasing power parity (PPP) condition (see Taylor and Allen, 1992; Chinn and Frankel, 2002). Besides the three traditional expectation schemes, we consider an additional expectation behavior based on the observed forward premium. Recall that under the joint hypothesis of rational expectations and risk neutral behaviour, the forward market premium - i.e. the spread between the forward and spot exchange rates - is an unbiased predictor of the

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[17] The standard adaptive model $E_t s_{t+\tau} - s_t = b_\tau(E_{t-\tau}s_t - s_t)$ defines the expected spot rate $E_t s_{t+\tau}$ as a weighted average of s_t, $s_{t-\tau}$, $s_{t-2\tau}$,..., with exponentially decreasing weights. For monthly data and for all $\tau > 1$ month, it is unlikely that agents refer to a weighted average of observations spaced by τ months. Such a hypothesis is all the more unrealistic as our τ values are 3 and 12 months while our data have a monthly frequency. Our early revision model defines $E_t s_{t+\tau}$ as a weighted average of actual and past monthly values of s_t, which seems more appropriate with our data.

change in spot rate.[18] Although many empirical contributions showed that the forward premium on foreign exchange is a poor predictor of the future change in spot rate, a significant group of forecasters may consider that the forward premium contains some relevant information on what the market reveals about the future value of exchange rates. Indeed, according to the economically rational expectations theory, this would be the case if the cost/aversion ratio is small enough for this component, which is rather intuitive since the forward rate is directly observable on the market. This reference to the forward rate allows us to introduce the *forward market component*, which we write as follows:

$$FOR_{t,\tau} = d_{t,\tau}(f_{t,\tau} - s_t) \tag{7}$$

where $f_{t,\tau}$ is the logarithm of the τ-month ahead forward exchange rate.[19] Such a forward premium component may capture two types of effects. The first one is a kind of mimetic behaviour resulting from the fact that, to form an opinion, a significant group of agents rely on the market opinion through the forward rate. The second effect conveys the influence of fundamentals in the expectation process since, according to the covered interest rate parity (CIRP) condition, the forward premium equals the difference between domestic and foreign interest rates. If the mixed expectation process were reduced to this component, equation (7) would represent the uncovered interest rate parity (UIRP) hypothesis. Weighting components (4) to (7), we obtain the following mixed expectation regression model:

$$E_t s_{t+\tau} - s_t = \kappa_\tau + \alpha_{t,\tau}(s_t - s_{t-3}) + \beta_{t,\tau}(E_{t-1}s_{t+\tau-1} - s_t) + \gamma_{t,\tau}(\bar{s}_t - s_t) + \delta_{t,\tau}(f_{t,\tau} - s_t) + \varepsilon_{t,\tau} \tag{8}$$

where $\alpha_{t,\tau}$, $\beta_{t,\tau}$, $\gamma_{t,\tau}$ and $\delta_{t,\tau}$ are composite coefficients comprising structural parameters of basic components and weighting coefficients, $\varepsilon_{t,\tau}$ a stochastic error term and κ_τ an intercept representing a possible systematic bias.

4. Empirical analysis

4.1. The data

Over our sample period, at the beginning of each month, *Consensus Economics* (CE) asks about 200 economists, foreign exchange operators and executives in various institutions (commercial and investment banks, forecasting agencies and industrial corporations) in over 30 countries to forecast future values of principal macroeconomic variables for the three and

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[18] Strictly speaking, when the spread is positive, the currency is sold at a "forward premium", while if it is negative, the currency is sold at a "forward discount". For simplicity, we consider here that the values of the so-called forward premium may be positive or negative.

[19] Our assumption that agents are concerned by the forward premium can be ascertained by showing that $E_t s_{t+\tau} - s_t$ and $f_{t,\tau} - s_t$ are correlated. Correlations over the sample period are 0.21 and 0.55 in the case of GBP/USD and 0.14 and 0.40 in the case of JYP/USD, for $\tau = 3, 12$, respectively.

the twelve month horizons.[20] The CE newsletter gives every month the "consensus" corresponding to the arithmetic average of individual expected values of exchange rates. These consensus time series are used in this paper. The CE requires a very specific day for the answers. As a rule, this day is the same for all respondents.[21] Accordingly, we consider the forward exchange rates $F_{t,\tau}$ ($\tau = 3,12$ months) and the spot rate S_t at the same day as the expected values. Spot and forward exchange rates, as well as the producer price indices used to construct PPP ratios for USA, UK and Japan, are issued from Datastream. Our empirical analysis covers the period November 1989 – December 2012. The rate of response of CE respondents for each exchange rate exceeds 50%. The experts answer only when they think they have a good knowledge about the variable of interest, and this allows assuming that those who respond are informed agents. Since the individual answers are confidential (only the consensus is disclosed to the public with a time lag) and since each individual is negligible within the consensus, it is difficult to claim that, for reasons which are inherent to speculative games, individuals might not reveal their « true » opinion. Note that these considerations only suggest that the responses are not distorted but they do not imply that the consensus represents an unbiased proxy of the market expectations. However, regarding the existence of the forward market for the two horizons, one can argue that there is an incentive for experts to compare their expected rate to the forward rate as a guideline. Doing so, they introduce a market dimension in their opinions by making in the same time a clear distinction between their expectations and the forward rates as suggested by the correlations between the expected changes in exchange rates and forward premia, which are very far from unity (footnote 19). Moreover, to interpret the consensus expectation as a market expectation, we only need to suppose that the latter equals the former plus an intercept and a white noise, implicitly captured in (8), and representing the systematic and the random components of the measurement error, respectively. For all these reasons, one can reasonably assume that the expectations provided by the respondent experts are representative of the market expectations.

4.2. The results

Our first concern is to check whether CF experts form their expectations rationally. We test for rational expectation hypothesis by performing unbiasedness and orthogonality tests using our survey data. If the null of unbiasedness is rejected, then there is no need checking for orthogonality to conclude that expectations are not rational. The test equation is the following:

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[20] Since the beginning of 1996, 1 month and 24 month time horizons are also included in the survey and published in the special bulletin named "Foreign exchange Consensus Forecasts".

[21] This day is the first Monday of the month until March 1994, and the second Monday since April 1994, except closed days (in this last case, the survey is dated at the following day). The effective horizons however always remain equal to 3 and 12 months. If, for instance, the answers are due on the 3rd of May (which was the case in May 1993), the future values are asked for August 3, 1993 (3 months ahead expectations) and for January 3, 1994 (12 months ahead expectations). The individual responses are then concentrated on the same day.

$$E_t s_{t+\tau} - s_t = \omega_\tau + \varphi_\tau (s_{t+\tau} - s_t) + \nu_{t+\tau} \tag{9}$$

where the conditions $\omega_\tau = 0$ and $\varphi_\tau = 1$ must be jointly satisfied and ν_t must be a white noise under the null. In addition, since our 3- and 12-month ahead expectations are observed in a monthly frequency, a possible overlapping data bias may affect the OLS variance-covariance matrix of estimates. In order to adjust the OLS standard errors in presence of overlapping data, Estrella and Hardouvelis (1991) suggest using the Newey-West methodology, which is robust to autocorrelation and heteroskedasticity in residuals. In testing (9) we follow their suggestion and estimate parameters ω_τ and φ_τ accordingly. Table 1 provides the unbiasedness test results.

Table 1. Unbiasedness tests

	JPY/USD		GBP/USD	
	3 months	12 months	3 months	12 months
ω	0.06	-0.004	0.19	0.10
	(0.62)	(-0.04)	(3.96)	(2.20)
φ	-0.03	-0.06	0.02	0.14
	(-0.99)	(-0.88)	(0.90)	(4.19)
$\overline{R}^2$	0.00	0.01	0.00	0.19
DW	0.82	0.28	1.28	0.46
Wald test	F(2,270)=651	F(2,261)=119	F(2,270)=911	F(2,261)=395
$Ho:(\omega=0, \varphi=1)$	p=0.00	p=0.00	p=0.00	p=0.00
Sample size	272	263	272	263

Notes. Numbers in brackets represent *t*-values. Estimations cover the periods 1990.02–2011.12 and 1990.02-2012.09 for 12-month and 3-month ahead expectations, respectively. To account for possible overlapping bias, regressions are run using Newey-West methodology (Bartlett Kernel, Andrew's automatic bandwith).

The Wald test that $(\omega_\tau, \varphi_\tau)$ jointly equals (0,1) for a given τ strongly rejects the hypothesis that expectations are rational. These results do not preclude, however, that agents have learned over time how to forecast rationally the future value of exchange rate. Some of the parameters in the case of GBP/USD are, indeed, slightly positive and significant although they are very far from the values under the null, suggesting perhaps the presence of a group of rational agents in the panel of forecasters.

We then modify equation (8) so as to express the expected change in exchange rate as a time varying weighted average of two components: a mixture of the four basic expectation processes employed by agents using limited information and the ex-post exchange rate return plus a white noise error term representing the rational agents' expectations. The reason why the ex-post return is not included into the mixture of processes as a fifth process is that either agents rely on limited (costly) information and linearly combine the basic expectation processes or they use all available (costless) information and form rational expectations. The

two groups are therefore exclusive at any point in time, with the possibility for the group of rational agents to grow over time in case of a learning process. For this purpose, we further modify equation (8) by assuming that the structural parameters are stable over the period and by removing the intercept κ_τ that proved insignificant in preliminary tests. As mentioned before, we assume that the target value is given by the PPP condition. We specify it (in logs) as $\bar{s}_t = p_{t-1} - p_{t-1}^{USA} + c$, where the shift-parameter c allows the regressive component $\bar{s}_t - s_t$ to have a zero mean over the sample period (i.e., to be mean-reverting), and where the price differential is lagged by one period because at the beginning of each month agents cannot observe the actual price indices but only the ones of the previous month (informational lag). In addition, the whole regressive component has been lagged by one period for optimality purposes, and this can be viewed as a delayed response of the forecasters to the observed target value (behavioral lag). Forward premium displays erratic movements possibly due to daily events at the days when observations are collected. It has been therefore smoothed using the Hodrick–Prescott filter with a rather low smoothing coefficient (200), to address the fact that agents pass over these erratic movements in forming their 3 month and 12 month ahead forecasts.

The model becomes then:

$$E_t s_{t+\tau} - s_t = \lambda_{t,\tau} \left\{ \alpha_\tau (s_t - s_{t-3}) + \beta_\tau (E_{t-1} s_{t+\tau-1} - s_t) + \gamma_\tau (\bar{s}_{t-1} - s_{t-1}) + \delta_\tau (f_{t,\tau} - s_t)_{HP} \right\}$$
$$+ (1 - \lambda_{t,\tau})(s_{t+\tau} - s_t + \hat{\xi}_{t+\tau}) + \eta_{t,\tau} \tag{10}$$

where $\lambda_{t,\tau} \in [0,1]$ is a time-varying parameter, $\eta_{t,\tau}$ a *Nid* error term with mean zero and constant variance and $\hat{\xi}_t$ is a simulated Gaussian white noise given its standard error $\hat{\sigma}_\xi$. Note that because $\hat{\xi}_{t+\tau}$ is uncorrelated with the dependent variable, the smaller $\hat{\sigma}_\xi$, the more the learning process should favor rationality. We rewrote the model for each currency in the form of a two-equation state-space representation where the state variables $\lambda_{t,3}$ and $\lambda_{t,12}$ have been assumed to be drawn from AR(1) processes. We gave to the standard error $\hat{\sigma}_\xi$ different values from zero (the case of perfect foresight) to, say, the standard deviation of the ex-post change in exchange rate $s_{t+\tau} - s_t$; for each of these values we carried out $m=10$ simulations of $\hat{\xi}_{t+\tau}$ and estimations of our state-space representation using the Kalman filter methodology[22]. We then assessed for each point in time the averages of the m estimated values of $\lambda_{t,\tau}$, that we denote $\bar{\lambda}_{t,\tau}$. A decrease in $\bar{\lambda}_{t,\tau}$ from 1 to zero would indicate that a learning process towards rationality is operating over time. But $\bar{\lambda}_{t,\tau}$ can also evolve continuously around a small and positive value, denoting a weak but stable influence of a group of rational agents, consistently with the unbiasedness test results we evidenced in the case of GBP/USD. We systematically found that $\bar{\lambda}_{t,3}$ and $\bar{\lambda}_{t,12}$ evolve so as to be non-

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[22] We do not report estimation results for the constant parameters α_τ, β_τ, γ_τ and δ_τ at this stage, but they are available upon request.

significantly different from one over the whole period, invalidating both the hypothesis of a rational group effect and the one of a rational learning effect. For illustration purposes, Figure 1 displays for both currencies the dynamics of $\bar{\lambda}_{t,3}$ and $\bar{\lambda}_{t,12}$ for $\hat{\sigma}_\xi = 0$, the most favorable case for rationality, in which case $\hat{\bar{\xi}}_{t+\tau} = 0$ $\forall t$ in (10).

Figure 1: Test of rational learning process
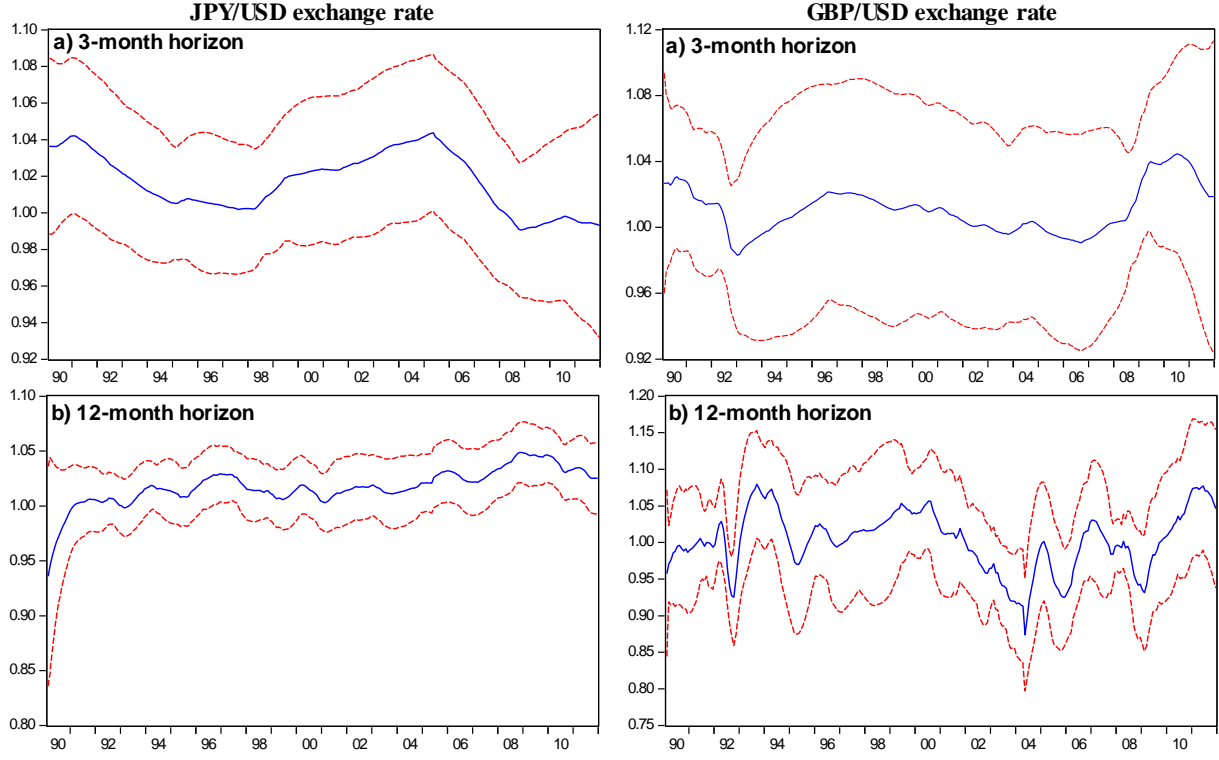
Notes. Figures represent the dynamics of the state variables $\lambda_{t,\tau}$'s in the equation (10) estimated using Kalman filtering under the condition $V(\hat{\bar{\xi}}_t) = 0$. Solid lines represent the smoothed estimates of $\lambda_{t,\tau}$, $\tau = 3, 12$. Dashed lines are the state estimates ± 2 standard-errors.

We thus drop the rational component of equation (10) and estimate directly the limited information mixed process. We expand equation (8) for the two horizons $\tau = 3$ and 12 and write, for each currency, a system of two equations whose error terms are contemporaneously correlated. Many reasons explain this correlation: first, for both horizons the exchange rate is defined as the domestic currency denominated price of the US Dollar; second, models for the two horizons include two common variables represented by the extrapolative and the regressive components. Here again, to account for the possible overlapping bias, we estimate our two-equation model using the system GMM method with heteroskedasticity and autocorrelation consistent (HAC) covariance matrix, which is also robust to contemporaneous correlation. Table 1 presents the estimation results for the two currencies JPY/USD and GBP/USD.

Table 2. GMM (HAC) system estimation results

	JPY/USD		GBP/USD	
	$\tau = 3$	$\tau = 12$	$\tau = 3$	$\tau = 12$
α_τ	0.19 (9.36)	0.04 (11.02)	0.14 (8.18)	0.04 (11.26)
β_τ	0.34 (30.44)	0.08 (47.75)	0.28 (20.00)	0.07 (29.24)
γ_τ	0.008 (5.40)	0.002 (3.86)	0.003** (1.27)	0.003 (4.22)
δ_τ	0.14* (1.73)	0.06 (3.03)	0.44 (3.59)	0.15 (3.16)
$\overline{R}^2$	0.78	0.95	0.58	0.85
DW	2.07	1.83	2.03	2.00
Wald p-value	0.00; 0.00		0.00; 0.00	
AIC	-1.77		-2.03	
SC	-1.66		-1.92	
HQ	-1.72		-1.99	
L	249.03		287.05	

Notes. Numbers in parentheses are the Student t-values. All estimates are significant at the 1% level, except the ones marked by a * and a ** that are significant at the 10% level and insignificant, respectively. Estimates are those of the parameters of Equation (8), among which the intercept, which has been systematically found to be insignificant, has been omitted. The estimation covers the period February 1990 – December 2012. The forward premium term has been smoothed using the Hodrick-Prescott filter. The instruments chosen are the contemporaneous and/or lagged values of the four components of model (8). To account for possible overlapping bias, the GMM with heteroskedasticity and autocorrelation consistent (HAC) covariance matrix is performed using a Bartlett kernel and Andrews automatic bandwidth. The first (second) entry of the Wald p-value is the probability of the null that the set of coefficients of the system estimated over the first (second) half of the period is significantly equal to that of the system estimated over the whole period.

All parameters are significant at the conventional levels and have the expected signs, implying that for each currency the four components play a role in the formation of expectations over the sample period. However, for both currencies, the Wald test rejects the null of stability of the coefficients at all levels. This finding suggests that the forecasters change over time the weights they attribute to the components of the mixed process. This is consistent with the theoretical analysis developed in section 2 where individual cost/aversion ratios, which determine the relevant variables, can themselves change over time. Generally speaking, instability in the coefficients can be accounted for by estimating model (8) using two alternative methods. Under the hypothesis that agents perform a discrete number of changes, the Qu and Perron (2007) method of system estimation with multiple structural breaks is appropriate. Controlling for structural breaks allows for estimating coefficients that can change from one sub-period to another but that are stable within each sub-period. Alternatively, if, as suggested above (see section 2.2), the changes in coefficients are

supposed to be continuous, an estimation method with time varying parameters is appropriate. In this case, the coefficients are assumed to evolve according to a stochastic dynamics and the model is given a state-space representation that can be estimated using the Kalman filter methodology. Another reason justifying the choice of this method is that ERET is consistent with the bayesian principle of the revision of information and the Kalman filter is among the appropriate methods to estimate a model based on such a principle (Doan et al, 1984; Racette and Raynauld, 1994). According to the ERET, at any time, new information is available with a new cost/aversion ratio, yielding forecasters to reassess the amount of information of each type they will purchase by minimizing their loss function. Updated proportions of categories of forecasters within the aggregate expectations or, in other terms, updated weights associated with the different expectation components result from the new optimal amount of information of each type collected.

Accordingly, we allow the slope-parameters of our two-horizon system model (8) to be time varying by reformulating the model as a state-space representation with two measurement equations for each currency. However, we do not specify eight state variables for the eight time-varying slope coefficients included in the system of equations, because assuming so would increase the non-linearity incorporated in the model and, given the size of the sample, would render the optimization process intractable. Rather, we assume that the time-varying coefficients of the 3-month model are linear combinations of the corresponding time varying coefficients of the 12-month model. The rationale under this specification is that (i) the 3-month horizon is included in the 12-month horizon, that is 25% of the time-span of the forecast horizons are common; (ii) the same experts respond to both currencies and at the same dates and (iii) the two exchange rates analyzed are defined as the number of domestic currency units per US Dollar.

The two-horizon model with stochastic parameters is then:

$$E_t s_{t+3} - s_t = (\phi_0^E + \phi_1^E \theta_t^E)(s_t - s_{t-3}) + (\phi_0^A + \phi_1^A \theta_t^A)(E_{t-1}s_{t+2} - s_t) + (\phi_0^R + \phi_1^R \theta_t^R)(\bar{s}_{t-1} - s_{t-1})$$
$$+ (\phi_0^F + \phi_1^F \theta_t^F)(f_{t,3} - s_t)_{HP} + \eta_{t,3} \quad (11a)$$

$$E_t s_{t+12} - s_t = \theta_t^E (s_t - s_{t-12}) + \theta_t^A (E_{t-1}s_{t+11} - s_t) + \theta_t^R (\bar{s}_{t-1} - s_{t-1}) + \theta_t^F (f_{t,12} - s_t)_{HP} + \eta_{t,12} \quad (11b)$$

$$\theta_t^E = \lambda_0^E + \lambda_1^E \theta_{t-1}^E + \upsilon_t^E \quad (11c)$$

$$\theta_t^A = \lambda_0^A + \lambda_1^A \theta_{t-1}^A + \upsilon_t^A \quad (11d)$$

$$\theta_t^R = \lambda_0^R + \lambda_1^R \theta_{t-1}^R + \upsilon_t^R \quad (11e)$$

$$\theta_t^F = \lambda_0^F + \lambda_1^F \theta_{t-1}^F + \upsilon_t^F \quad (11f)$$

where $\eta_{t,\tau} = N(0, \sigma_{t,\tau})$, $\tau = 3,12$, and $E(\eta_{t,3}, \eta_{t,12}) = \rho$. Equations (11a) and (11b) are the measurement equations defining the mixed forecast models while equations (11c) to (11f) stand for the state equations describing the dynamics of the time-varying parameters entering into the forecast models. In preliminary estimations, we again accounted for a possible overlapping bias by introducing a moving average specification of order $\tau - 1$ for the

residuals (Hansen and Hodrick, 1980) that is 2 lagged residuals in (11a) and 11 in (11b). All moving average terms were found to be insignificant, indicating that the overlapping bias should not be such as to affect the estimates. Figures 2 and 3 exhibit the time-patterns of the four estimated stochastic parameters θ_t^i, $i=\{E,A,R,F\}$, in the case of the JPY/USD and GBP/USD exchange rates, respectively. Table 3 provides the estimation results using the Kalman filter methodology.

**Figure 2: Time-varying parameters of the mixed forecast process
for the JPY/USD exchange rate**
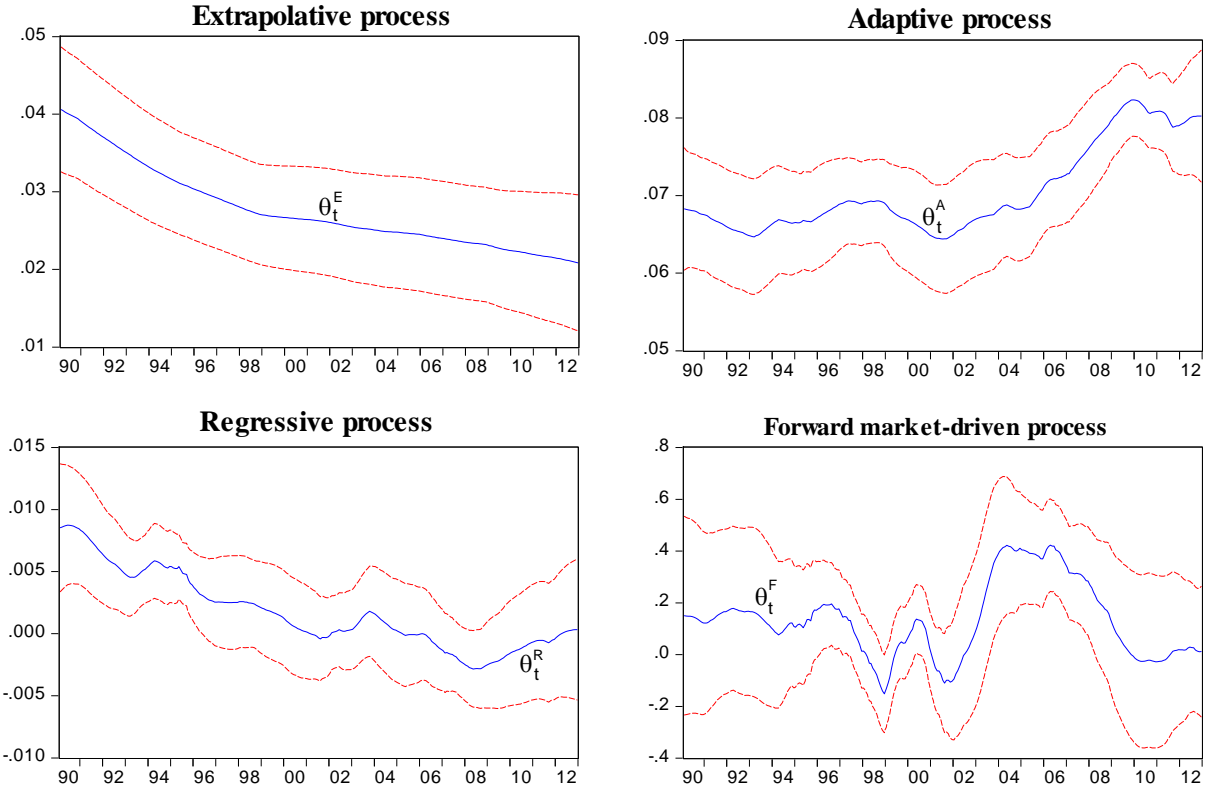
Notes. Solid lines represent the smoothed estimates of the state variables. Dashed lines are the state estimates ± 2 standard-errors.

Figure 3: Time-varying parameters of the mixed forecast process for the GBP/USD exchange rate
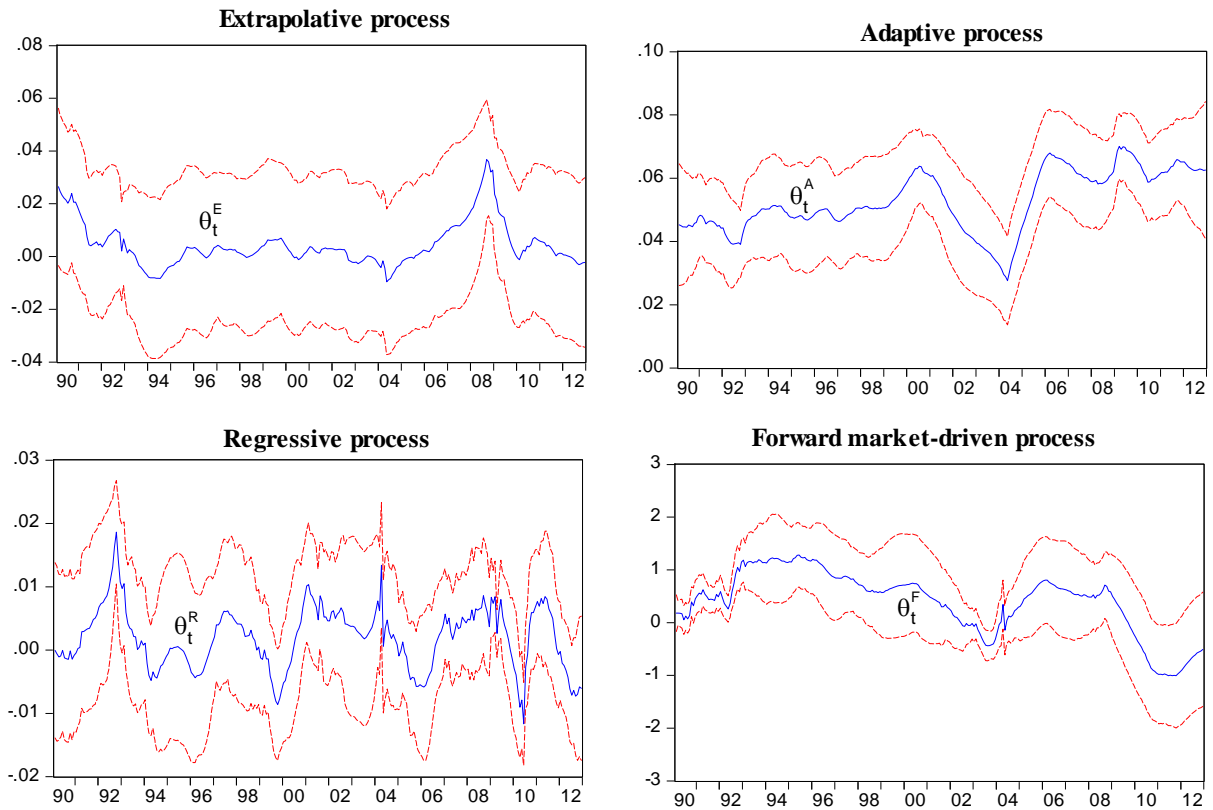
Extrapolative process

Adaptive process

Regressive process

Forward market-driven process

Notes. Solid lines represent the smoothed estimates of the state variables. Dashed lines are the state estimates ± 2 standard-errors.

Table 3. Kalman filter estimation results

	JPY/USD		GBP/USD	
	$\tau = 3$	$\tau = 12$	$\tau = 3$	$\tau = 12$
Measurement equations				
ϕ_0^E	-		0.06	
			(0.01)	
ϕ_1^E	4.83		3.12	
	(0.43)		(0.66)	
ϕ_0^A	-		-	
ϕ_1^A	4.44		4.52	
	(0.12)		(0.18)	
ϕ_0^R	-		-0.01	
			(0.002)	
ϕ_1^R	1.96		2.20	
	(0.44)		(0.21)	
ϕ_0^F	-0.36		-	
	(0.07)			
ϕ_1^F	3.60		1.31	
	(0.47)		(0.13)	
k_τ	-2.11	-5.04	-2.54	-5.79
	(-18.47)	(-52.80)	(0.10)	(0.16)
State equations				
λ_0^E	-		-	
λ_1^E	0.997		0.901	
	(0.002)		(0.05)	
λ_0^A	-		-	
λ_1^A	0.999		0.997	
	(0.001)		(0.004)	
λ_0^R	-		-	
λ_1^R	0.989		0.880	
	(0.01)		(0.03)	
λ_0^F	-		-	
λ_1^F	0.975		0.976	
	(0.02)		(0.02)	
k_E	-15.16		-9.83	
	(2.00)		(0.81)	
k_A	-13.77		-11.34	
	(0.81)		(0.55)	
k_R	-14.85		-11.11	
	(0.87)		(0.30)	

k_F	-5.97 (0.80)		-3.53 (0.34)	
ρ	0.02 (0.003)		0.01 (0.002)	
$\overline{R}^2$	0.84	0.97	0.74	0.97
R_D^2	0.80	0.87	0.80	0.93
AIC	-1.86		-2.44	
SC	-1.65		-2.40	
HQ	-1.77		-2.42	
L	271.62		337.96	

Notes. Numbers in parentheses are the standard deviations. For each exchange rate, the estimated state-space model is given by the system (11a) to (11f) and the estimation covers the period February 1990 – December 2012. The estimates are obtained by setting to zero the insignificant intercepts indicated by a dash. To ensure positivity, the unconditional variances of $\eta_{t,\tau}$, $\tau = 3,12$, and υ_t^i, $i=\{E,A,R,F\}$, are estimated as exp(k_τ) and exp(k_i), respectively. ρ is the contemporaneous covariance between the two signal residuals. AIC, SC and HQC stand for Akaike, Schwarz and Hannan and Quinn information criteria for the two-horizon system estimation.

It can be seen from Figures 2 and 3 that none of the state variables θ_t^i include uninterruptedly the zero line into its 95% confidence bounds. Moreover, except for θ_t^E that allows for a narrow interval of constant positive values in the case of GBP/USD, all the state variables evolve over time. These results suggest that agents revise continuously their expectation generating scheme by relying on a mixed process at any point in time. The covariance ρ among the residuals of the measurement equations is very significant, justifying the joint estimation of the two horizon processes (Table 3). A striking result is that the 3-month model time-varying parameter coefficients ϕ_1^i range from 1.96 to 4.83 and from 1.31 to 4.52 for the JPY/USD and GBP/USD exchange rates respectively, so that the changes in the parameters of the 3-month forecast model are much wider than those of the 12-month process. This shows that changes in time-varying parameters are dampened as the horizon is longer, possibly because the information costs are better controlled over time, favoring of a more stable forecast model in the "long" run. Besides, we examine the intrinsic behavior of forecasters in the "short" run and in the "long" run. We categorize the forecasters into two broad behavioral groups: the group of chartist agents, who rely on historical patterns of exchange rates and therefore use extrapolative and adaptive processes, and the group of fundamentalist agents, who base their forecasts upon economic fundamentals and focus on regressive and forward market processes. We now aim at measuring the relative importance of the chartist and the fundamentalist behavior. At this end, denoting V_C and V_F the variance of the chartist and fundamentalist expectations respectively, we calculate for each horizon and currency the ratios $V_C/(V_C+V_F)$ and $V_F/(V_C+V_F)$. Table 4 provides these variance ratios. It turns out that both chartists and fundamentalists' behavior are significant and that chartists are largely dominant over fundamentalists for both currencies and horizons. While, for the JPY/USD, the relative scores of chartists and fundamentalists do not change according

to horizons, in the case of GBP/USD the relative importance of fundamentalists (chartists) increases (decreases) substantially with the horizon. Interestingly, these results are in accordance with a questionnaire-based study by Taylor and Allen (1992) who find that more than 90% of traders use chartist analysis to predict future changes in exchange rates and that chartist and fundamentalist expectations are more representative of the short and longer terms, respectively.

Table 4: variance ratios of chartist and fundamentalist expectations

	JPY/USD		GBP/USD	
	Chartists	Fundamentalists	Chartists	Fundamentalists
3-month	97.1	2.9	86.1	13.9
12-month	96.9	3.1	72.1	27.9

According to the information criteria and the log likelihood values L, the model with time-varying parameters outperforms the one with stable parameters (8). However, the significance of this improvement should be checked. To this end, we perform the likelihood ratio test $LR = 2[L(\hat{\Theta}) - L(\tilde{\Theta})]$ that is distributed as a χ_m^2, where $\hat{\Theta}$, $\tilde{\Theta}$ and m are the vector of parameters of the unrestricted model (11), the vector of parameters of the restricted model (8) and the number of restrictions, respectively. The test statistic LR equals 45.18 in the case of JPY/USD and 103.72 in the case of GBP/USD. Comparing these values to the statistic χ_8^2, which is equal to 15.51 at the 5% level and to 20.1 at the 1% level[23], we can conclude that the time-varying parameters model (11) very significantly outperforms the constant-parameters model (8). We also checked for the goodness of fits by using the conventional adjusted coefficient of determination $\bar{R}^2$ and a modified measure, R_D^2, assessing the goodness of the fit with respect to a random walk plus drift model. The R_D^2 values for JPY/USD indicate that the residual variance of the measurement equation is 0.20 and 0.13 times that of the random walk model for the 3 month and 12 month horizons, respectively. In the case of GBP/USD, the corresponding rates are 0.20 and 0.07. These results show that our time-varying parameters model outperforms the random walk model. The $\bar{R}^2$ values indicate good fits for both currencies, as also shown from Figures 4 and 5.

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[23] The restrictions allow for reducing the time-varying state variables into constant parameters. Setting to zero the residual variance (i.e. setting $k_i = -\infty$, $i=\{E,A,R,F\}$) and the slope parameter in each state equation fulfills this condition and leads to $m=8$.

Figure 4: Observed and fitted values of the JPY/USD exchange rate expectations
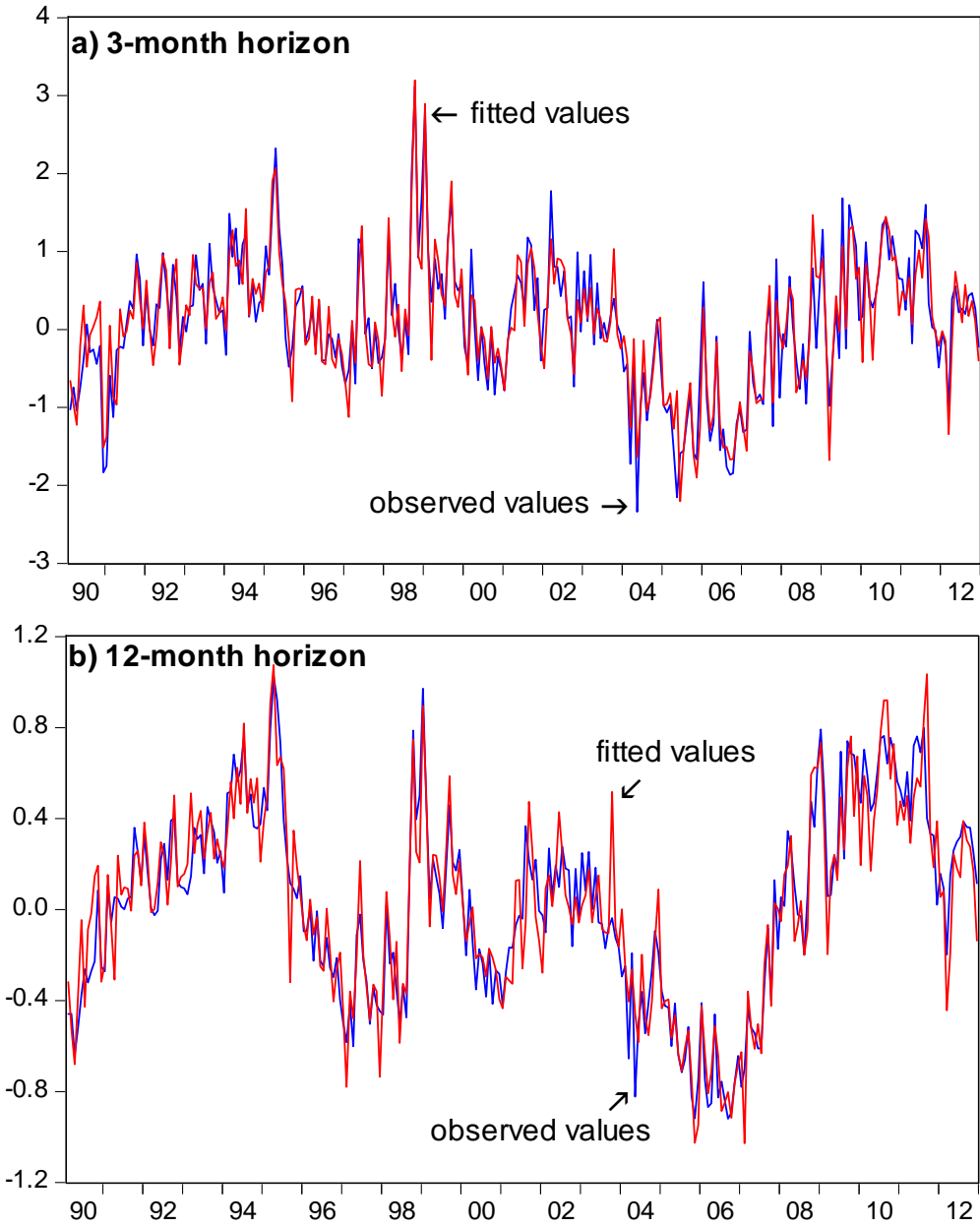
Figure 5: Observed and fitted values of the GBP/USD exchange rate expectations
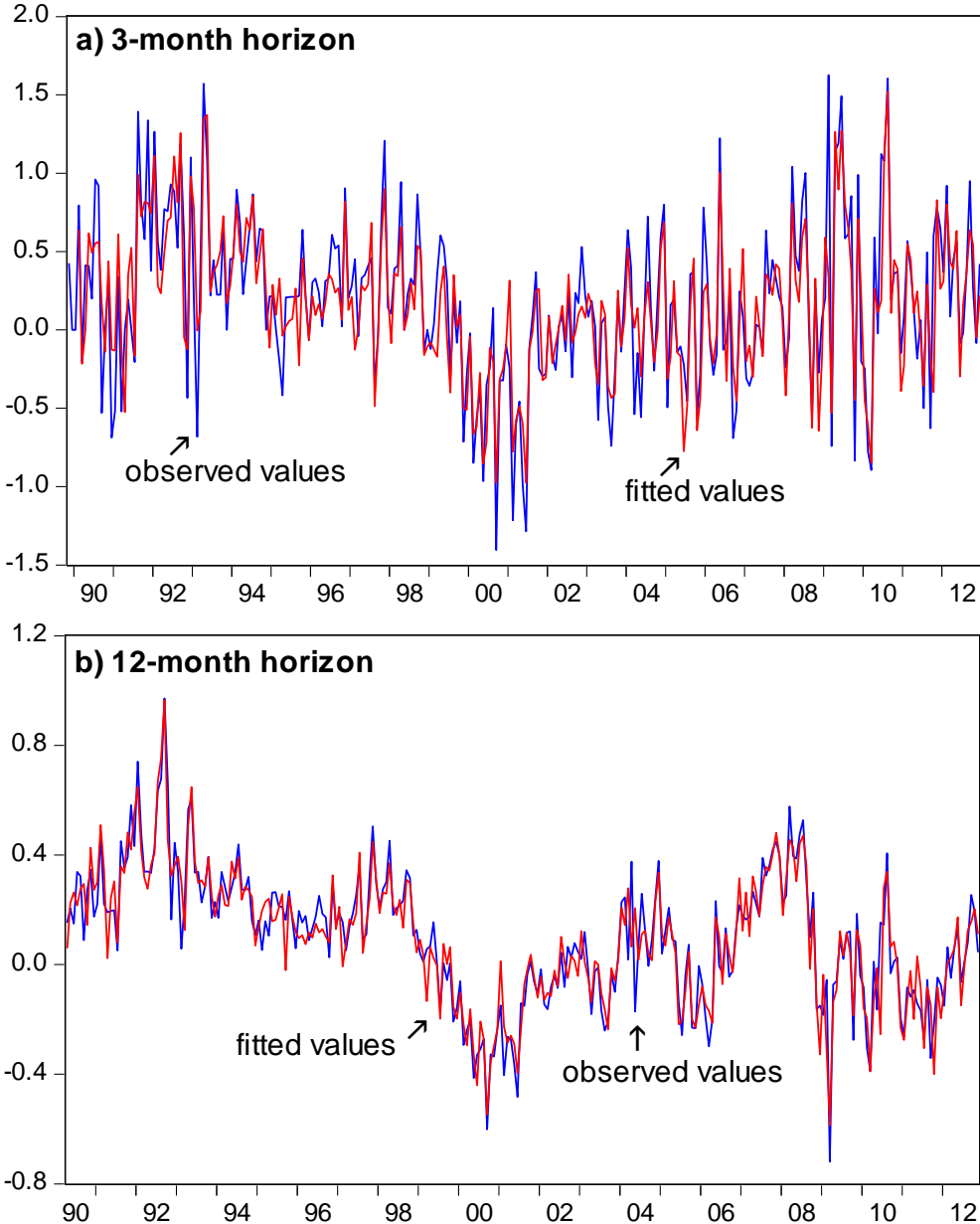
5. Conclusion

Using experts' expectations provided by the monthly survey conducted by Consensus Economics, we aim to model simultaneously the 3-month and the 12-month ahead expectations for the JPY/USD and the GBP/USD exchange rates. According to the economically rational expectations theory, the lower the cost/aversion ratio associated to a given information, the higher the weight of the corresponding component in the expectation process because the larger the proportion of agents using this component. We showed that the dynamics of aggregate expectations is not consistent with the rational expectation hypothesis

but is attributable to a limited information process defined as a linear combination of the extrapolative, regressive, adaptive components and also a forward-market component, each of them being affected by a time-varying weighting coefficient. These weights were estimated using the Kalman filter methodology which is a suitable approach for representing the revision of information process suggested by the theory. This mixed model with time-varying parameters is shown to strongly outperform the same mixed model with constant weighting parameters, emphasizing the importance of taking into account the variability of the heterogeneity of beliefs. We further represented through the extrapolative and adaptive components the chartist behavior referring to the past dynamics of exchange rate, and through the regressive and forward-market components the fundamentalist behavior referring to PPP and UIRP, respectively. Our results show that these two kinds of behavior contribute significantly to the formation of the 3-month and 12-month ahead expectations, the chartist behavior being largely dominant for these two horizons. However, the relative importance of the fundamentalists is found to increase with the horizon. Overall, the rejection at any date of a significant group of agents whose behavior conforms to REH joint to the fact that no simple traditional process explains by itself the dynamics of expectations contradict most of the approaches in the literature where a single process among the conventional processes is assumed to be employed by agents at any time with a constant coefficient.

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